Georgia Tech Simulator Sickness Screening Protocol

Georgia Tech School of Psychology Tech Report GT-PSYC-TR-2013-01

Thomas M. Gable & Bruce N. Walker

Thomas.Gable@gatech.edu, Bruce.Walker@psych.gatech.edu

October 21, 2013

Sonification Lab
School of Psychology
Georgia Institute of Technology
654 Cherry Street
Atlanta, GA, USA
http://sonify.psych.gatech.edu
Phone: +1-404-894-8265

ABSTRACT

We discuss the development of the Georgia Tech Simulator Sickness Screening Protocol (GTSSSP), a new, efficient, and effective driving simulator sickness screening method. Simulator sickness can cause a small but significant proportion of driving research participants to feel ill. In addition to the unpleasant symptoms and discomfort, simulator sickness can impact driving performance, and may lead to withdrawal from a study and the loss of time and data. There is an ongoing need for an efficient prospective method to identify participants who are likely to experience simulator sickness, before it happens. Existing screening methods have been either purely survey-based, relying on reported tendencies to experience motion sickness; or they can identify when a participant is becoming ill, but are not designed to predict illness. Thus, we developed a screening procedure that includes a baseline survey (administered via an in-vehicle touchscreen interface), a brief but effective screening drive in the simulator, and a post-drive follow-up survey. The survey software automatically scores the participant's pre- and post-drive responses, leading to a recommendation for continuing or exiting the driving study; and data are logged for later analysis and longitudinal evaluations. The GTSSSP was developed for the simulator at Georgia Tech, but is intended to be made available for deployment elsewhere. This paper points to previous work in the area through a short literature review, and then discusses the process of creating the screening procedure, followed by instructions for how to use the GTSSSP protocol.

Keywords: Driving, Driving Simulator, Simulator Sickness

1. INTRODUCTION

Driving simulators are becoming increasingly pervasive and popular, as they enable more affordable and safe driving research than real vehicle driving, Simulators can place participants in driving situations that would otherwise be too dangerous, logistically complicated, or expensive to replicate in real life [1]. Technological advances are further expanding the capabilities and realism of simulators, and bringing down costs and complexity. While there are many positives about driving simulators, a major drawback in their use, and what some believe could prevent virtual environments from reaching their full potential, is simulator sickness (SS) [7].

1.1 Simulator Sickness

SS is similar to motion sickness (MS) but the physical and mental feelings are usually somewhat less severe, and SS does not occur in as high a proportion of people [6]. SS symptoms can include headache, dry mouth, drowsiness, disorientation, dizziness, and in some cases nausea and vomiting [1, 2, 6]. There is an ongoing debate about the causes of SS; for a thorough overview see the excellent overview by Brooks and colleagues [1]. Most researchers agree that in fixed-based simulators, SS is related to elements of the visual experience. However, there remains some debate as to whether SS can be completely eliminated through technological improvements to the simulator, or whether some people will always be susceptible to illness [6, 7]. SS can have adverse consequences on an experiment. Side effects such as decreases in psychomotor control can potentially affect performance data, and can also affect participant drop out rates [2]. Any loss of participants, and therefore data, can be particularly costly (both in time and money) to the research project.

SS is also an important topic for researchers to consider for ethical reasons. IN all research—including studies involving driving simulators—there is a need to avoid harming the subjects in any way [1]. Thus, it is important to monitor participants, and regularly check for signs they are becoming ill from the simulated driving. If they are showing symptoms, their participation can be halted. This is, in fact, the main goal behind the careful development of a simulator sickness assessment survey at Clemson University [1]. However, the discomfort and illness of SS can often have a fairly early rapid onset (especially for older drivers), and can persist well after the end of the simulated driving [1]. Thus, it is imperative not only to monitor the development of SS symptoms, but to proactively screen out individuals who are likely to develop SS, before they even begin their participation in a driving study. [7] That, then, was the impetus behind the development of the GT SSSP.

1.2 Preventing Simulator Sickness

There are a number of factors concerning the simulators themselves that can affect the prevalence of SS. Physical factors such as the temperature of the environment where the simulator is being used can affect the prevalence—a cooler temperature can help to decrease levels of SS [1], and we have found that a gentle breeze from a fan can help. While researchers have some control over these types of physical factors of the simulators they use, many factors such as the viewing angle, simulator type, and hardware choices cannot be changed retroactively.

Some factors that researchers *can* control are related to the scenarios that the participants drive. For instance, some studies have found that many turns and shallow curves may increase levels of SS [8, 10]. Scenarios with intersections have also been found to increase SS, as have simulations where drivers had to perform non-severe braking [10, 11]. In one study when participants drove on a simulated highway they were found to have higher rates of SS symptoms than individuals who were on slower roads, suggesting speed or optical flow on the screen may play a role in SS [9].

Time spent driving in a simulator has also been found to affect prevalence of SS. Some researchers have claimed a positive, almost linear, relationship between time in a simulator and SS, concluding that a safe maximum time in a simulator is approximately one hour [7]. Other researchers, however, have found that there seems to be a point at around an hour of exposure where SS prevalence stops increasing and possibly even starts to decrease [2]. Researchers have found that repetition may be used to help decrease SS effects: as participants repeat their use of a simulator, the likelihood they experience SS decreases in a liner fashion. Other results show that acclimation to a simulator followed by a few days off produces a decline in SS, the next time the participants use the simulator [3, 7].

1.3 Measuring Simulator Sickness

While preventing SS is preferable in most instances, there is still a chance of SS occurring and for this reason it can be useful to measure the appearance and evolution of SS symptoms. Initial measurements of SS were done through the completion of either the Pensacola Diagnostic Index (PDI) or the Pensacola Motion Sickness Questionnaire (MSQ) [5, 4]. These two measures both have limitations however, and have been criticized and adapted.

Kennedy, Lane, Berbaum, and Lilienthal [5] determined that the MSQ, while widely used, was not as applicable to measuring SS as it could be. Through factor analysis they took the 28 symptoms included in the MSQ and adapted them based on the symptoms relevance in the SS domain or if the word was misleading. They then split the resulting 16 symptoms into three distinct categories, including oculomotor, disorientation, and nausea in an effort to make the measure more multidimensional [4]. The resulting measure was simpler and had improved diagnostic capability from the MSQ and was named the simulator sickness questionnaire (SSQ).

Years later another set of researchers made an attempt to improve upon the current ways of measuring SS. Gianaros et al. [4] argue that multiple response systems may be activated by real or apparent motion and that when an individual states they are feeling SS they are most likely referring to a complex set of symptoms. Additionally they stated that some of these response systems may be more involved than others in the negative effects felt during SS. Gianaros et al. determined that the best way to measure SS would be through a questionnaire that created a score for each of these dimensions, not one total score, allowing the survey to address component parts of SS. They decided to include four dimensions in their measure including gastrointestinal, central, peripheral, and sopite (i.e., fatigue)-related, the last of which was new in diagnosing and measuring SS. Gianaros and his fellow researchers ended up with a final list of 16 words including: sick to stomach, faint-like, annoyed/irritated, sweaty, queasy, lightheaded, drowsy, clammy/cold sweat, disoriented, tired/fatigued, nauseated, hot/warm, dizzy, like I am spinning, as if I may vomit, and uneasy. Each of these factors were scored from 1 to 9 on severity and then scores were calculated. The completed questionnaire results were highly correlated with PDI scores indicating a good measurement for motion sickness. This become known as the motion sickness assessment questionnaire (MSAQ) and is another common measure of SS.

As the need for more refined SS assessment and screening continued, Brooks and colleagues evaluated the SSQ and the MSAQ surveys [1]. The researchers decided that the MSAQ was more applicable to the identification of SS symptoms, but only after adapting the scale used in the survey from a 1 to 9 scale to a 0 to 10 scale. This adaptation was done because participants wanted to be able to rate their symptoms on a 0 (none) to 10 (maximum) range, rather than 1 to 9 [1]. The new questionnaire was administered after an acclimation session of driving, and after each session of driving in the research study. Brooks et al. reported that they were able to preemptively identify individuals who were likely to discontinue their participation in a driving study, at great than 90% accuracy [1]. While this is an effective way to know if a participant is becoming sick during your study, and should therefore stop driving, it is not useful as a true pre-screening tool to identify those individuals who should not even *start* driving in your simulator study.

1.4 Predictive Screening for Simulator Sickness

Measuring SS symptoms as they occur can be helpful in an attempt to decrease the likelihood of participants experiencing more severe SS, or for it to affect data, but sometimes considering these factors is not enough; a method to truly predict sickness must be employed [1]. Asking participants about previous MS or SS episodes, or their propensity to get motion-related illness has been used, but with only limited utility, likely because the SS that participants in a driving study may experience are only partially related to any MS symptoms they may have experienced in the past. [1, 11]

In our experience (and this view is shared by other researchers we have spoken to), individuals who are going to develop symptoms of SS will often begin to do so very soon after driving, within the first minute or two. Others have written about the use of acclimation scenarios to help ease participants into the simulated driving experience, and to try to reduce the SS prevalence [1]. In contrast, our approach was to create a brief driving scenario to introduce the participant to simulated driving maneuvers that could trigger a slight feeling of SS. The key to this is to have enough SS-inducing maneuvers or situations so that the participants who will normally experience SS can quantify the increase in SS during the short drive (and thus stop, and not even start in the main driving session); but not so much SS induction that the individual feels particularly uncomfortable. Similarly the maneuvers should be slight enough that someone who will not usually experience SS during an experimental driving session does not "over-induced" into SS during the screening process. That is, the assessment needs to be both sensitive and specific. Finally, one must consider the time constraints of a study and attempt to keep the driving scenario brief in order to not increase overall study durations significantly.

The current protocol is an attempt to strictly define a protocol to be used for predictively screening for SS in the National Advanced Driving Simulator (NADS) MiniSim located in the School of Psychology at Georgia Institute of Technology. The goals for the protocol are to be efficient with time, effective (sensitive and specific), and involve a simple implementation for the researcher. The remainder of this paper provides more details of the creation and proper implementation of the surveys and the scenario that are involved in this procedure.

2. PROTOCOL DEVELOPMENT

2.1 Overview

The GT Simulator Sickness Screening Protocol (GTSSSP) is a brief, efficient method of predicting whether a research participant will experience symptoms of simulator sickness during a subsequent research drive. The protocol involves (1) a computer-based baseline survey of the participant's current state, followed by (2) a brief driving scenario intended to uncover latent tendencies toward illness, and then (3) a post-drive re-administration of the survey (with immediate and automated scoring of the responses). Based on the score after the second survey, the participant is either cleared for participation in the main experimental driving session(s), or thanked and asked to discontinue before the main sessions have been started.

Figure 1. Driving simulator setup at Georgia Tech School of Psychology. Three screens for the main driving task are seen; a fourth screen is used for the dashboard displays. A touchscreen monitor connected to a separate infotainment unit is fixed to the right of the steering wheel; this is where the electronic version of the screening survey is displayed.

2.2 Baseline and Post-Drive Survey

The survey component of the GTSSSP protocol is based heavily on the adapted and refined MSAQ as described by Brooks et al. [1]. Our survey asks for the participant's current feeling on a 0 to 10 scale where 0 is "not at all" and 10 is "severely" for the same 16 questions as well as an additional question of "floating" (see Table 1). To make the administration easier, faster, more private, and support the automated scoring and logging of data, the survey is presented (both times) electronically, via a computer program written in cross-platform Java. This application is displayed on a touch screen infotainment unit that is attached to the dashboard and is within reach of the participant when they are seated in the simulator (see Figure 1 for setup). Before and after driving the test scenario, participants answer each of the 17 questions, one at a time, by moving a slider bar along a range of 0 to 10. With the touchscreen computer, the participant can simply use his or her finger to move the slider to the desired location; of course, a mouse can be used to interact with the software if a touchscreen monitor is not available. The results of the survey are saved to the infotainment computer for comparison to the post-drive responses, scoring, and archiving of responses.

Table 1. Questions in the Survey Portion of the GT Simulator Sickness Screening Protocol

"I feel…"

1.	sick to my stomach
2.	faint-like
3.	annoyed/irritated
4.	sweaty
5.	queasy
6.	lightheaded
7.	drowsy
8.	clammy/cold sweat
9.	disoriented
10.	tired/fatigued
11.	nauseated
12.	hot/warm
13.	dizzy
14.	like I am spinning
15.	as if I may vomit
16.	uneasy
17.	floating

2.3 Scenario

The scenario used in the GTSSS protocol was created using the MiniSim creation tool ISAT. While creating the scenario, factors that can increase SS were considered and some were employed to increase the likelihood of an individual experiencing SS, without creating a scenario that was going to be unrealistic or create more experiences of SS than the typical research driving scenarios would. The scenarios include intersections, non-severe braking, and gentle curves. Optic flow was also implemented through other traffic passing the driver, but due to limits on time the speed was never increased to a full highway level.

The simulation begins with the participant at a stop at the side of the road. There is one lane going in each direction, with traffic moving in both directions. Instructions on the simulator screen instruct the driver to put the car in drive and proceed down the road amongst the traffic. Participants then have to stop at a stoplight; when the light turns green the participants proceed through the intersection. (We have noted that nearly all of the participants who experience any symptoms will already begin to notice them by the time they come to the first stop light.) Soon, the road begins to curve to the left and changes to two lanes going in each direction. After navigating the curve, the cars ahead of the driver begin slowing down to a stop; the participant driver does the same. Instructions then appear on the simulator screen, telling the driver to put the car in spark and complete the post drive survey. The driver simulation ends after about two minutes of driving time.

2.4 Data Logs

The pre- and post-drive surveys are logged in a plain text file for future analysis. These data can be aggregated within a lab to monitor overall rates of SS symptoms. They may also be combined with the data being compiled here at GT, in order to assess broader population-level base rates, and investigate the roots and remedies of driving simulator sickness.

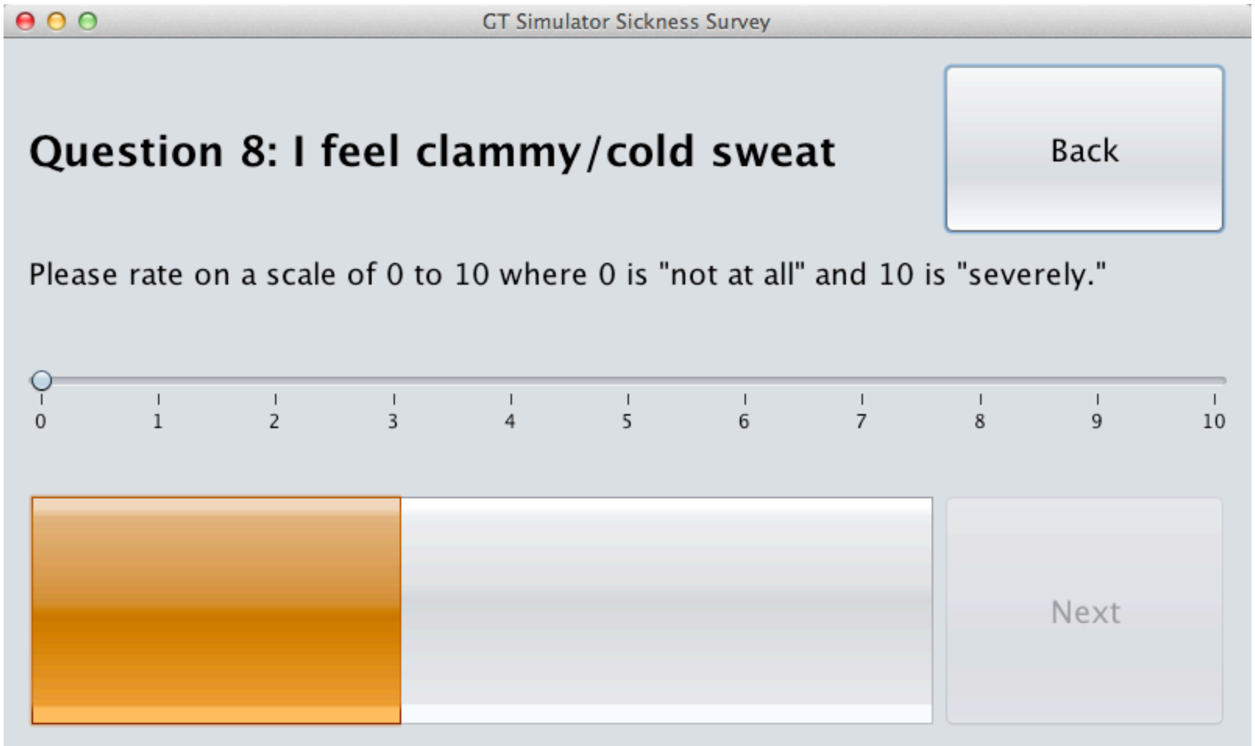

Figure 2. Screenshot of the electronic survey in the GTSSSP, before a participant has interacted with the slider. Once the participant selects a number by touching the slider bar, the "Next" button becomes available. The larger orange bar at the bottom of the screen is a progress indicator, showing that the participant is nearly halfway through the survey.

3. PROTOCOL IMPLEMENTATION

The implementation for the protocol has been made as simple as possible so little to no training is required for researchers to apply this technique. Once the simulator and infotainment unit computer and monitors have all been turned on and the researcher has started up the MiniSim software, the researcher runs the screening survey application. This Java application is typically located in a folder titled GTSSSP. Once opened, the GTSSSP application will request an experiment name and participant number, which will be entered by the researcher, typically via the keyboard. The participant will then complete a short demographics page followed by the

17 questions (one per page; see Table 1) that make up the baseline pre-drive survey. On each of the pages a single question is displayed and the participant rates their current feeling on that factor. To respond, participants move a slider with their finger, between values of 0 and 10, before going on to the next question. Participants must interact with the slider before being able to move forward in the survey but can always move backwards to change previous answers if necessary (See Figure 2 for an example).

After the survey is completed the application will instruct the participant to complete the 2-minute driving scenario; at this point the researcher initiates the simulated driving scenario via the MiniSim control computer. The participant drives through the scenario as they would in a regular vehicle, observing all traffic laws. Following completion of the driving scenario participants return to the post-drive survey on the infotainment computer, and respond to the same 17 questions (no demographics) based on their current feelings.

Once the post-drive survey is completed, the computer tallies the answers for the 17 questions and a score is calculated and displayed discreetly on the final page (see Figure 3 for example). The score is then used to determine if an individual should continue to participate. For the paper version of the protocol the scoring is defined as "If any single rating on the post-drive survey is greater than or equal to 5 more than pre-drive survey, or if any three of the ratings on the post-drive survey are above a 3 as compared to the pre-drive survey, it is recommended that the participant not continue." Therefore the electronic form gives a 1 for every 3-point increase in any question and a 3 for any 5-point increase; and if any score total is higher than 3, the participant should not continue. Additionally, if at any point during the evaluation scenario the participant feels any symptoms of SS it is recommended the simulation be discontinued and the participant not continue. If a participant completes this protocol without any signs of SS they may then continue in the experiment sessions. However, if a participant does show any signs of SS, attempts should be made to make them as comfortable as possible, while the symptoms subside. This involves turning off the simulator screens, letting them stay seated (or moving them to a more comfortable chair if they desire), and possibly giving them water. Participants who have shown initial signs of SS during this screening protocol typically have not developed severe symptoms or significant discomfort, due to the brevity of the screening drive (that is part of the point of this screening protocol). As a result, their symptoms also generally fade quite quickly and they are generally ready to be dismissed from the study in a few minutes.

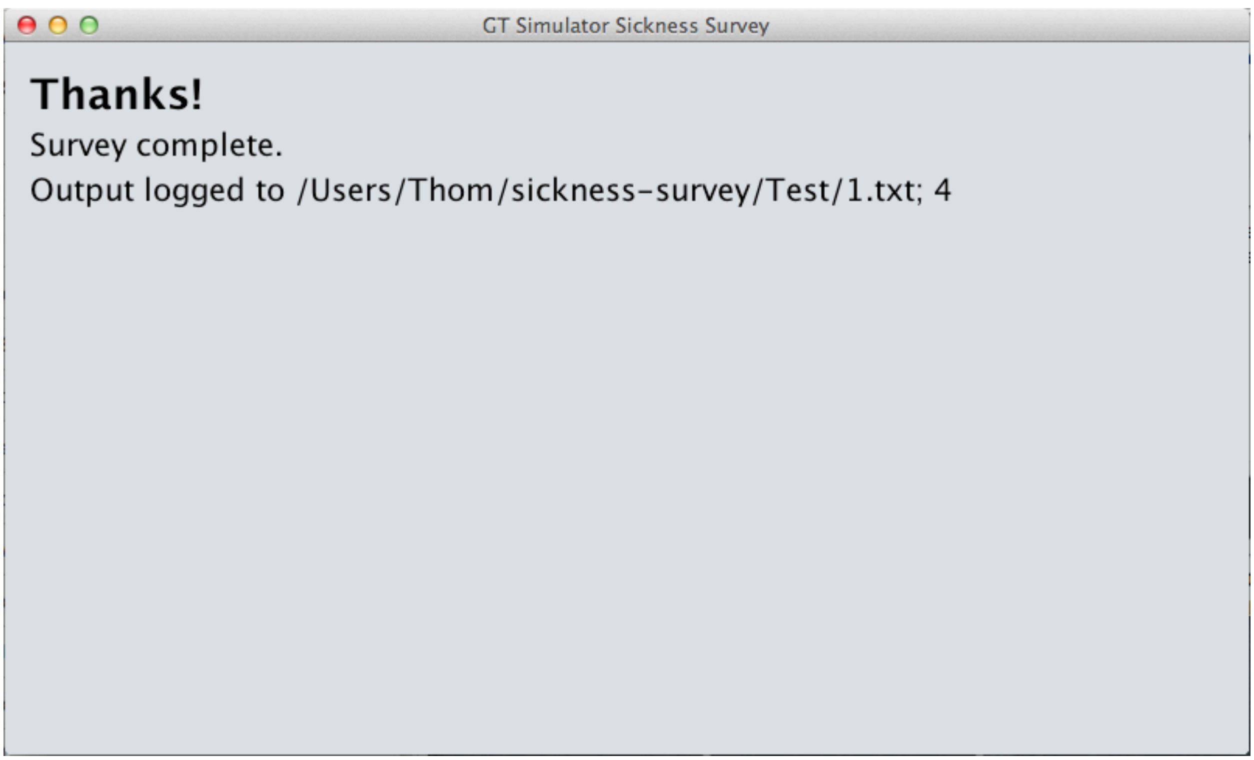

Figure 3. The final page of the electronic version of the GTSSSP survey is shown. The page shows where the file with all of the ratings and data has been saved, followed by a number representing the participant's score after the semicolon. In this case the score was a 4, meaning that the participant should not continue.

4. DISCUSSION

The application of this simulator sickness screening protocol is intended to help both participants and experimenters who are taking part in research involving a driving simulator, especially—but not necessarily—the NADS MiniSim. It is the authors' expectations that by applying this predictive screening protocol before every driving simulator study individuals who are prone to SS will be identified quickly before the actual experiment begins with a high rate of success and reliability. In doing so this will save participants who are sickness prone from starting a study and then feeling the need to push on even though they feel sick. It will also assist experimenters in saving time not only in addressing participants who will become SS part way though the experiment but in not spending too much time attempting to screen for SS.

5. ACKNOWLEDGMENTS

Thanks to Ben Stolvitz for creating the touch screen application used in this study and to the people at Nation Advanced Driving Simulator and Brianna Tomlinson for helping us to finalize the driving scenario. Portions of this work are supported by a National Science Foundation Graduate Research Fellowship (DGE-1148903).

6. REFERENCES

[1] Brooks, J. O., Goodenough, R. R., Crisler, M. C., Klein, N. D., Alley, R. L., Koon, B. L., ... & Wills, R. F. (2010). Simulator sickness during driving simulation studies. *Accident Analysis & Prevention*, *42*(3), 788-796.

[2] Cobb, S. V., Nichols, S., Ramsey, A., & Wilson, J. R. (1999). Virtual reality-induced symptoms and effects (VRISE). *Presence: Teleoperators and Virtual Environments*, *8*(2), 169-186.

[3] Domeyer, J. E., Cassavaugh, N. D., & Backs, R. W. (2013). The use of adaptation to reduce simulator sickness in driving assessment and research. *Accident Analysis & Prevention*.

[4] Gianaros, P. J., Muth, E. R., Mordkoff, J. T., Levine, M. E., & Stern, R. M. (2001). A questionnaire for the assessment of the multiple dimensions of motion sickness. *Aviation, space, and environmental medicine*, *72*(2), 115.

[5] Graybiel, A., Wood, C. D., Miller, E. F., & Cramer, D. B. (1968). *Diagnostic criteria for grading the severity of acute motion sickness* (No. NAMI-1030). NAVAL AEROSPACE MEDICAL INST PENSACOLA FLA.

[6] Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology*, *3*(3), 203-220.

[7] Kennedy, R. S., Stanney, K. M., & Dunlap, W. P. (2000). Duration and exposure to virtual environments: Sickness curves during and across sessions. *Presence: Teleoperators and Virtual Environments*, *9*(5), 463-472.

[8] Lee, G. C., Yoo, Y., & Jones, S. (1997). Investigation of driving performance, vection, postural sway, and simulator sickness in a fixed-based driving simulator. *Computers & industrial engineering*, *33*(3), 533-536.

[9] Mourant, R. R., & Thattacherry, T. R. (2000, July). Simulator sickness in a virtual environments driving simulator. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 44, No. 5, pp. 534-537). SAGE Publications.

[10] Roe, C., Brown, T., & Watson, G. (2007). Factors Associated with Simulator Sickness in a High-Fidelity Simulator. *Education*, *251*, 5A.

[11] Watson, G. (2000, July). A synthesis of simulator sickness studies conducted in a high-fidelity driving simulator. In *Proceedings of Driving Simulation Conference* (pp. 69-78).